



The Need and Challenges for Distributed Engine Control

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Outline

- Motivation for Distributed Engine Control
- Distributed Engine Control as a Solution
- How Distributed Engine Control Modifies Control System Thinking
 - Engine System – Control System Interaction
 - Control System – Impact of Control Architecture
- Summary



Motivation

Engine perspective

Need to improve performance

Lower SFC:

Compression Ratio

▶ Higher T4 ▶ Higher OPR

Higher thrust/weight:

Power Density of the Core

▶ Higher T4 + Higher aerodynamic performance

Higher temperatures – less space

Controls perspective

Enables improved engine performance

- Tighter margins
- New control applications



Do more under increasingly severe environmental constraints ???

Electronics as a system vulnerability



Motivation

The Wider, Longer Term Outlook

The engine depends on controls ... but *controls depends on electronics*

In the short term advances in electronics provide **more capability** in a **smaller volume** at **lower power**

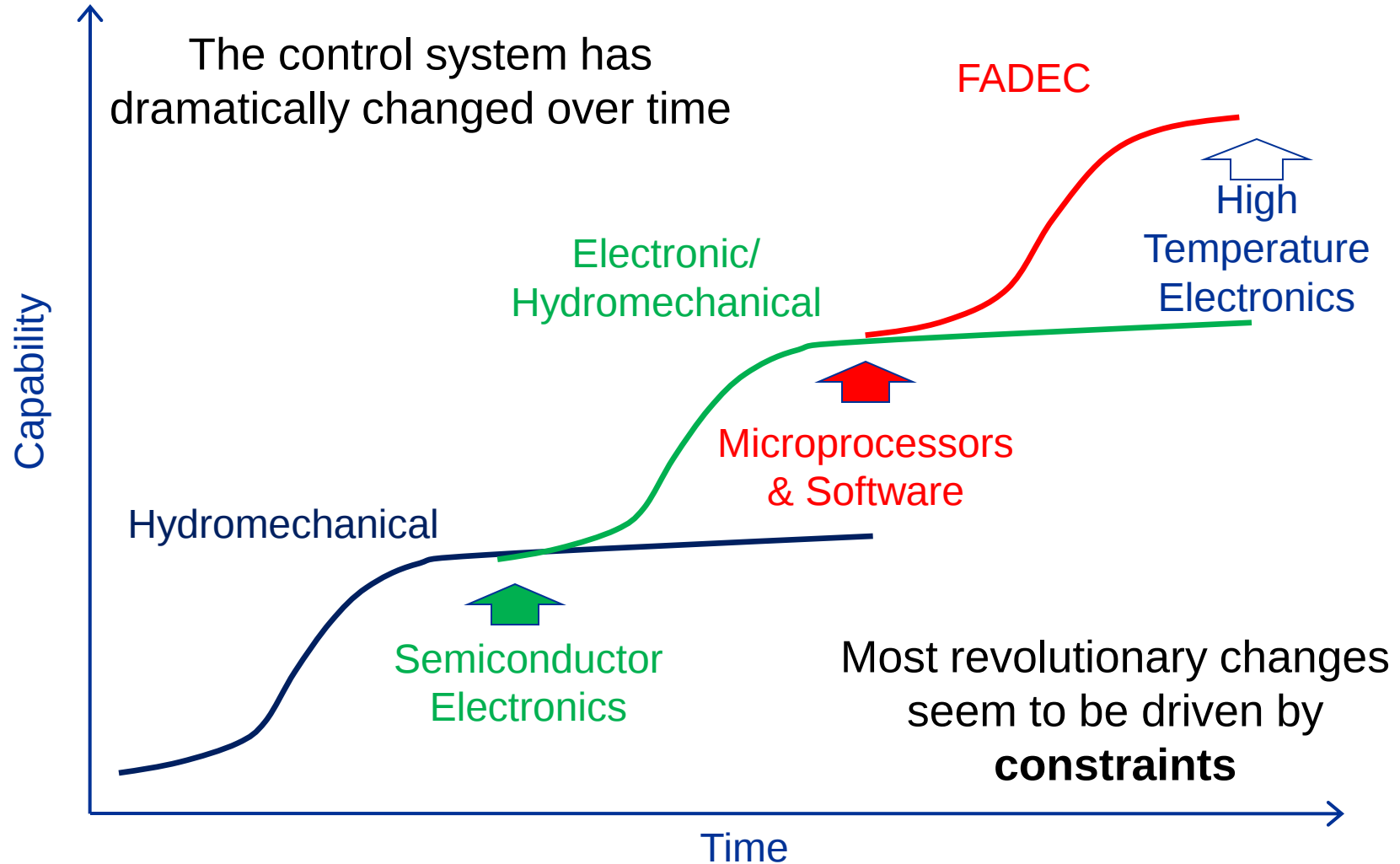
In the long term advances in electronics drive **more control system redesign** and **more re-validation, re-verification, and re-certification** to accommodate the obsolescence of electronic components

Analogy

Imagine not being able to procure replacement turbine blades from any source for any price



Gas Turbine Engine Control Architecture

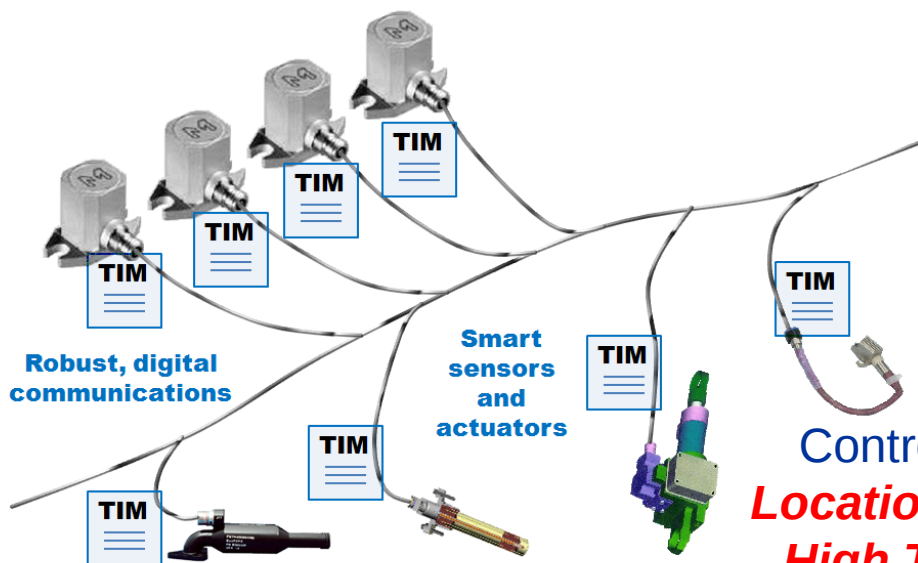


Distributed Engine Control

New Capability that Directly Addresses
Unique Constraints Imposed on the
Control System

based on

Modular, Flexible, Scalable Control
Architecture



Public release
photo Intel.com

Processing-Intensive
control functions based on
commercial electronics are
Location Independent

Control Effector functions are
Location Dependent and require
High Temperature Capability



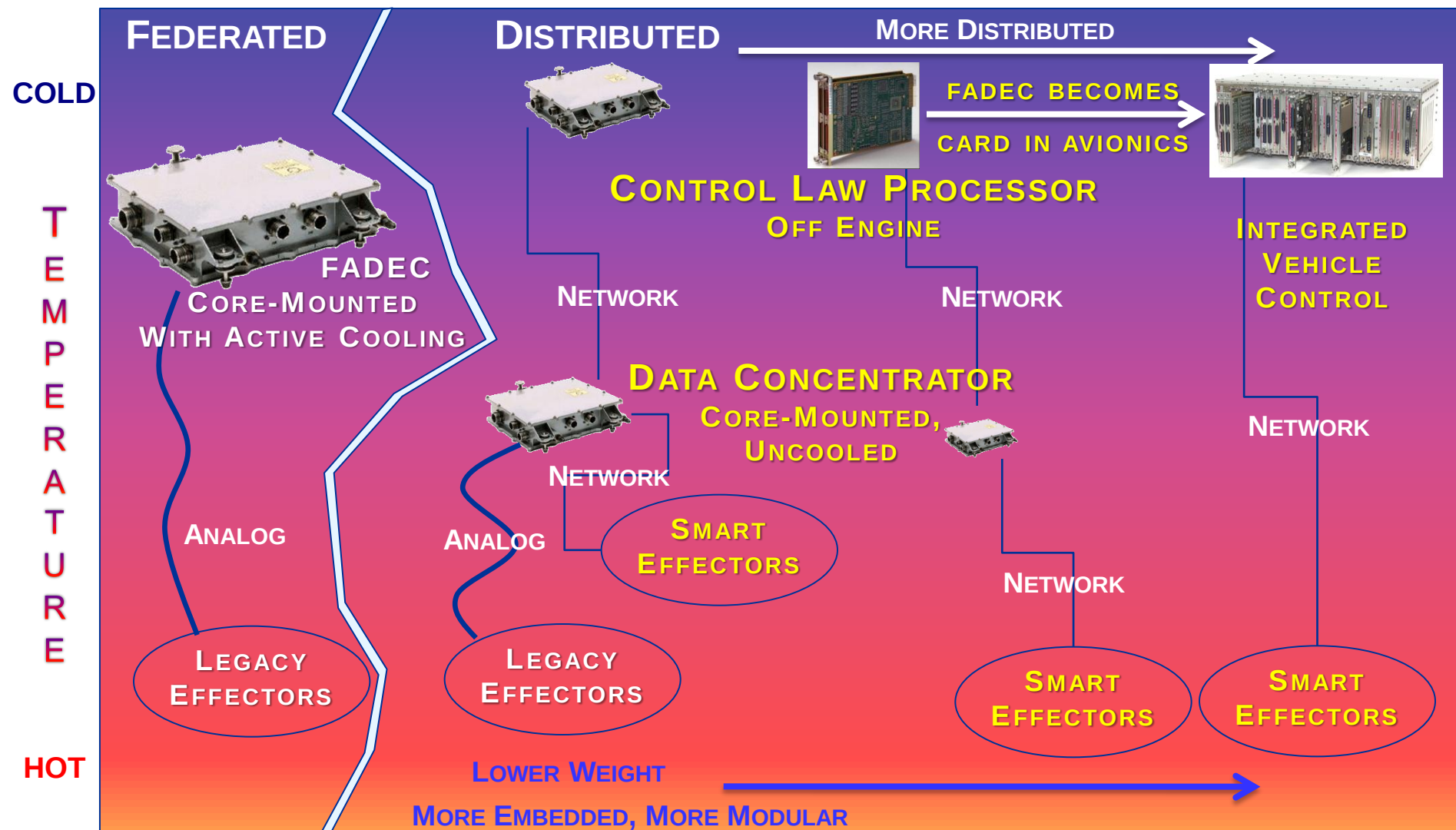
Revolutionary Change – Unique Challenges

The turbine engine environment presents a more severe challenge to the fundamental operation of a distributed control system

- Relative to automotive applications that use commercial components, higher temperature electronics being developed for the turbine offer a reduced capability in order to provide the necessary high reliability
- How do we safely apply this technology?
- How do we develop growth in its capability?
- Do we understand system design and system interactions?
- Can we effectively communicate these new requirements across the entire supply chain?

Integration

The Evolution of Engine Control Architecture





Engine System – Control System Interaction

Perception - Why *break* a perfectly good control system?

The engine is a complex system, its development is organized around highly specialized components – imperfect system knowledge

The control system is unusual - it interfaces to every part of the engine system.

- Direct – sensors and actuators
- Virtual - operation
- Hidden – e.g. wiring harnesses

Traditional Control Systems are highly affected by constraints and Control Engineers Traditionally Perform System Integration

- Engine system design
- Control system design
- FADEC design
- Software design



Eliminate hardware dependencies

Control System – Impact of Control Architecture

High temperature electronics clearly enables **more distributed** engine control because processing functions become location independent

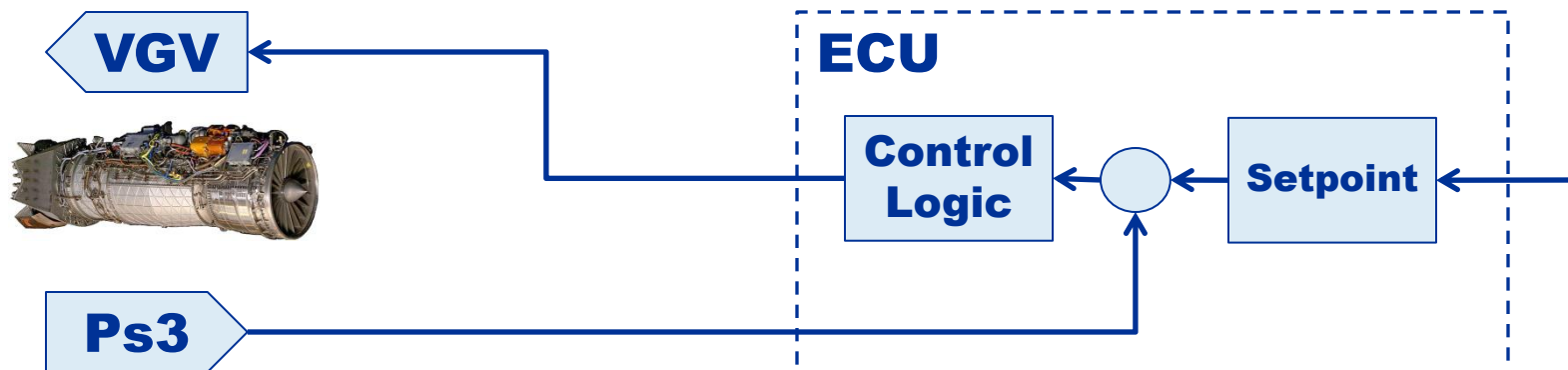


**Embedded Processing
and analog functions
at the Effector**



**Complex Processing in a
more benign environment**

The control system integration focuses on **data flow** analysis between control elements





Control System – Impact of Control Architecture

Engine system integration

- Focuses on “**how to integrate the control system**” – a network issue
- Not “*how does control integrate with the engine system*” – a hardware issue



For example:

- A “smart” Ps3 sensor produces scaled, linearized pressure data in engineering units for direct use in the control system
- The device is integral to the compressor, not added
- The data is integral to the control system

This shift in approach opens up the possibility of simplifying the evaluation of new technology insertion at an earlier stage of development.

The potential for a smart Ps3:

- Compressor stability detection by sensing pip / modal pressure fluctuation
- Stability control by embedded FFT processing, control logic, and closed loop control of a stability actuator (bleed or flow control)



Customers Don't Buy Technology, They Buy Capability

We need to be able to develop quantifiable metrics in terms that can be understood outside of the controls discipline

- Decision makers require information
 - Understanding of the benefits
 - Understanding of the constraints
 - Understanding the risk of
 - action – implementing new technology
 - Inaction – not implementing new technology



Summary

- Distributed Engine Control (DEC) is a revolutionary technology to alleviate engine system constraints on the control system.
- DEC offers significant potential to insert new beneficial control applications on the engine with reduced system impact.
- DEC drastically alters the engine integration environment and the supply chain.
- New tools are needed to fully understand DEC technology and to produce quantitative information for engine system decision makers regarding when and how to apply new control technology.



Questions?